

## SHRIMP CULTURE RESEARCH IN CONTROLLED ENVIRONMENTS\*

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Although there are some big differences between shrimp and catfish, we are finding there are also some very similar problems involved in raising them for profit. In fact, there are a great many problems all aquaculturists have in common. One of the purposes of this paper is to encourage more communication between people working with different species since I feel we can be of considerable help to each other.

At the Galveston National Marine Fisheries Service Laboratory we are working with several different problems related to marine shrimp culture. These include nutritional studies and the formulation of suitable, inexpensive diets, studies of the reproductive processes of shrimp directed toward finding ways to induce maturation and spawning in captivity, and studies of shrimp diseases, their diagnosis, treatment and prevention. A fourth problem we are working on, the one I want to discuss in this paper, is the development of economical techniques for high-density culture of shrimp.

It is not necessary to reiterate the advantages and disadvantages of high-density culture or the use of environmental control with this group. I would like to say the National Marine Fisheries Service group in Galveston has made a strong commitment to the development of intensive culture methods for shrimp because we believe this is the approach most likely to be profitable in the United States. It may surprise you to

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hear that the problems related to water supply and pollution, which have been discussed earlier in this meeting, are serious ones for marine aquaculture as well as for freshwater culture. These problems have been some of the key ones leading to our research on high-density culture. I believe it's safe to say that the advantages of a very intensive approach are clear enough so that many farmers will try this approach once the costs have been reduced.

Economics also enter the picture when we begin looking for methods of controlling the environment. Generally, methods exist for controlling environmental conditions and water quality but we have neither identified the most economical methods for use in aquaculture nor learned how to apply existing technology to individual aquaculture situations.

In our research with environmental control systems for penaeid shrimp, we group control efforts into four broad areas: (1) temperature control, (2) particulate waste removal, (3) dissolved waste removal, and (4) aeration. To develop the most economical means of exercising control in these four areas we are experimenting in a closed system where all water is being recirculated. Tanks are concrete with rounded corners and sloping bottoms (Mock, Salser and Ross, MS).

#### Temperature Control

One of the big advantages of a system with little or no water exchange is that it simplifies temperature control. With shrimp it permits the extension of the growing season with little heat input. Although year-round rapid growth is attractive economically, it does not justify the heating and discarding of any quantities of water with fuel prices at today's levels.

We have successfully used two types of greenhouse covers, corrugated fiberglass and air-inflated polyethylene, to trap heat in our closed systems. During the coldest months, supplemental heating has been required to maintain temperatures of  $26^{\circ}\text{C}$  to  $28^{\circ}\text{C}$  which are optimum for shrimp. Because of the relatively high specific heat of water it stores the sun's energy during the day and cools slowly during the night.

A related problem, that of preventing heat loss, has not been explored adequately. We believe much heat loss can be prevented by using insulating materials in the tanks and by providing covers for the tanks at night.

A greenhouse structure is also useful as a support for shading materials if cooler water temperatures are desired.

#### Particulate Waste Removal

Particulate wastes in the shrimp tanks consist of waste feed, feces and algae. A variety of filters have been tested during our preliminary experimentation. Among those tested, the simple screens, filter bags, pressurized filter beds and centrifuges were all unsatisfactory either because of labor requirements or because of high energy requirements of the methods. The approaches which apparently have the most promise involve the use of gravity and simple sedimentation as the means of separation. Two forms have been tested by scientists at the Galveston Laboratory. One of these is a simple sedimentation tank and the other is a plate separator designed for us by the Pielkenroad Separator Company, Houston, Texas. The plate separator is much more efficient in terms of water flow rates and space requirements. An interesting discussion of the design of sedimentation tanks is presented by Jensen (1972).



Of special interest to us is the development of an efficient technique which permits the easy recovery of the particulate waste materials from the system. These wastes can be disposed of most easily in a solid or semi-liquid form. In addition when these wastes are available in quantity they have value which should not be overlooked. The most obvious use is as an agricultural fertilizer if the salt content is low. There are also good possibilities of recycling these wastes as a part of the food for the animal being reared or as food for a second species. The production of methane from wastes such as crop residues, algae and animal wastes is attracting increasing interest. Methane, a useful fuel, can also be produced from aquaculture wastes. It takes roughly 15 pounds of dry organic wastes to produce methane with the equivalent fuel value of one gallon of gasoline (Lindsley, 1974). Following the methane production process a sludge still exists which might be used as feed or fertilizer. With increasing costs of all feed products and transportation, aquaculturists are being forced to consider carefully the possible recycling of any waste products available.

#### Dissolved Waste Removal

Although many methods of removing specific dissolved chemicals exist, the ones which have found wide use in sewage treatment all involve the use of living plants to extract the wastes from the water. The trickling filter is one of the most efficient techniques for this purpose. We have used biological filter beds consisting of crushed oyster shell and of a specially designed plastic substrate, the Pielkenroad trickling filter medium, which is designed to facilitate recovery of sloughed plant growth and to insure continuous operation for long

periods with little maintenance. Again we are seriously interested in the recycling of the biological growth which develops on the substrates of trickling filters. Because this growth includes a variety of bacterial, fungal, algal and animal life it has desirable characteristics as a food or a food supplement for aquatic animals.

A modified biological filter, the bio-disk filter, which has been used successfully for sewage treatment (Autotrol Corporation, 1971; Antonie, 1970) has been used as a method of removing dissolved wastes from our raceways. This filter consists of a series of disks which are half submerged in water and which rotate on an axle. Because of the motion of the disks and their frequent exposure to air, this filter is efficient with respect to its surface area. The sloughed biological growth is also easily recovered from this filter. Rates of removal of specific dissolved wastes in both the trickling filter and the bio-disk filter systems are discussed by Ross, Mock and Salser (MS).

In our greenhouse-covered raceways both phytoplankton and attached filamentous algae grow rapidly. The presence of sunlight and the high nutrient levels in the water provide an environment conducive to rapid plant growth. This plant growth, using the sun's energy, converts many of the dissolved wastes to plant material. Much of the plant material is removed as a portion of the suspended particulate matter, thus contributing to the removal of dissolved wastes from the system.

Here again, the aquaculturist may be able to recover some valuable by-products from the waste removal system. Even the less sophisticated approach of using water with dissolved wastes to fertilize a pond or less intensive culture system has potential economic value. Lindsley (1974) discusses proposals to rear water hyacinths or algae simply for their value for the production of methane.

### Aeration

The category of aeration includes a variety of functions such as oxygenation of the water, air stripping of dissolved gases and the circulation of water in a system. These functions are all performed in our systems through the use of air-lift pumps. In addition to aerating the water as it is pumped, the air-lifts are used to create a directional flow in the tanks by attaching elbows to their upper end at the surface of the water.

The continuous circulation and mixing insure that all the water is well oxygenated. This helps prevent the formation of anaerobic conditions in which toxic gases are produced, and insures the rapid oxidation of waste products. The water circulation rate is adjusted to keep most particulate waste material suspended in the water column.

The removal of undesirable dissolved gases such as hydrogen sulfide, ammonia and excess carbon dioxide is a beneficial side effect of the aeration call air stripping.

The air-lift pumps are used to transfer water to and from the filtration equipment thereby eliminating the need for individual electric pumps. The air-lifts are operated using air from a low-pressure, high-volume air blower.

### Energy Considerations

The energy requirements of controlling environmental conditions are critical cost factors. The most economical control methods are those which utilize sunlight, plant growth, gravity or waste products as sources of energy rather than those which require the use of high pressure pumps, chemical treatments or consumption of fossil fuels. A partial solution



to the high costs seems to lie in the recycling of wastes. However, we are just beginning to learn how to apply the engineering know-how of wastewater treatment to the particular problems of aquaculture. The encouraging preliminary results from our efforts to rear several species at high densities in controlled environments lead us to believe that more efficient and economical methods can be developed. These results will certainly be accomplished sooner if we can open more lines of communication between aquaculturists working with different species.

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